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Contribution from the Office of Public Roads
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER July 12, 1915.

PROGRESS REPORTS OF EXPERIMENTS IN DUST PREVENTION AND ROAD PRESERVATION, 1914

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CONTENTS

	Page
Experiments at Lemon City, Fla.	1
Experiments at West Palm Beach, Fla.	7
Supplementary Report of Experiments at Miami, Fla., 1913	16
Supplementary Report of Experiments on Rockville Pike, Maryland, 1913	17
Supplementary Report of Experiments at Washington, D. C., 1912	22
Supplementary Report of Experiments at Chevy Chase, Md., 1912	25
Supplementary Report of Experiments at Chevy Chase, Md., 1911 Project	29
Supplementary Report of Experiments Made at Jamaica, N. Y., 1911	34
Supplementary Report of Experiments Made at New York, N. Y., and Ridgewood, N. J., 1910	37
Supplementary Report of Experiment Made at Boise, Idaho, 1910	37
Supplementary Report of Experiment Made at Ames, Iowa, 1910	38
Supplementary Report of Experiments Made at Knoxville, Tenn., 1910	39
Supplementary Report of Experiments Made at Youngstown, Ohio, 1909	40
Supplementary Report of Experiments Made at Newton, Mass., 1908	42
Supplementary Report of Experiments Made at Garden City, Dodge City, Bucklin, and Ford, Kans., 1908	43
Supplementary Report of Experiment Made at Bowling Green, Ky., 1907	44

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PROFESSIONAL PAPER.

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CONTENTS.

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EXPERIMENTS AT [illegible]

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CONTENTS.

	Page.
Experiments at Lemon City, Fla	1
Experiments at West Palm Beach, Fla	7
Supplementary report of experiments at Miami, Fla., 1913	16
Supplementary report of experiments on Rockville Pike, Maryland, 1913	17
Supplementary report of experiments at Washington, D. C., 1912	22
Supplementary report of experiments at Chevy Chase, Md., 1912	25
Supplementary report of experiments at Chevy Chase, Md., 1911 project	29
Supplementary report of experiments made at Jamaica, N. Y., 1911	34
Supplementary report of experiments made at New York, N. Y., and Ridgewood, N. J., 1910	37
Supplementary report of experiment made at Boise, Idaho, 1910	37
Supplementary report of experiment made at Ames, Iowa, 1910	38
Supplementary report of experiments made at Knoxville, Tenn., 1910	39
Supplementary report of experiments made at Youngstown, Ohio, 1909	40
Supplementary report of experiments made at Newton, Mass., 1908	42
Supplementary report of experiments made at Garden City, Dodge City, Bucklin, and Ford, Kans., 1908	43
Supplementary report of experiment made at Bowling Green, Ky., 1907	44

EXPERIMENTS AT LEMON CITY, FLA.

OILS, TAR PREPARATION, CALCIUM CHLORIDE-CORALLINE ROCK.[1]

The second series of experimental bituminous treatments of coralline rock roads in Dade County, Fla., under the direction of the United States Office of Public Roads, was installed on Biscayne Drive about one-quarter of a mile north of Lemon City. The bituminous materials used were several barrels of the oils remaining from

NOTE.—This bulletin reports the results from a number of experiments in dust prevention and road preservation conducted by the Office of Public Roads in 1914. The materials used and methods employed in the experiments, the several kinds of roads and varying conditions of traffic, and analyses of materials and cost data are given.

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[1] Information regarding a similar series of experiments constructed at Miami, Fla., in 1913, will be found in Bulletin of the United States Department of Agriculture No. 105.

the 1913 experiments at Miami and two water-gas tar products donated by the manufacturers for this purpose. The oils had been stored without protection from the weather, and were in poor condition, principally through the presence of water.

The excellent results obtained in experiment No. 6 of the original series of experiments at Miami could be attributed beyond question to the use of screened rock instead of the "run of the bank" material used in the other experiments. Consequently only the screened-rock type of construction was followed in these experiments. The rock was quarried from the Lemon City pit, which was the nearest source of supply. It was comparatively soft and decidedly unsuitable for bituminous work of this nature, due to its tendency to crush to powder when the screened-rock course was even lightly rolled to make it conform to cross section. In some portions this created a surface condition similar to that existing in experiments 3, 4, and 5 at Miami, described in the previous report. This soft quality and the presence of a considerable proportion of fine material, which it was found impracticable to screen out, made the surface very susceptible to the binding effects of rain.

The work began at station 0+00 at the north end of the project on January 6 and continued intermittently until February 7.

The general method consisted in scarifying and regrading the old surface, after which a course of new screened rock was spread to a loose depth of 2½ inches. This course was shaped by a very light rolling before spreading the bituminous material over it. The excess of bitumen was absorbed by a covering of sufficient fine white sand from near-by pits, and the road was finished by thorough rolling.

Frequent rains and showers during the work considerably delayed its progress and produced surface conditions which prevented the best results being obtained. It is clearly demonstrated that the greatest difficulty to be overcome in any future large-scale construction of bituminous coralline-rock roads is the harmful effect of rains on the prepared surface before the application of the bitumen. The high cementing power of the rock causes it to bind strongly when wet, unless the dust is entirely removed in the screening. The surface is thus rendered more or less impervious, and the treatment becomes in effect only a surface treatment. This difficulty may be met by performing such work in the dry season of the year, or by keeping at all times the prepared surface work and the bituminous application well together.

The equipment was the same as that used at Miami, consisting of a 10-ton gasoline roller, scarifier, grader, two 1-barrel heating kettles, and hand-pouring pots. Analyses of the bituminous materials used are given in the tables following.

TABLE 1.—*Analyses of asphaltic petroleums used in experiments at Lemon City, Fla.*

	Light.	Heavy.
	Experiment 2.	Experiments 1, 3.
Specific gravity 25°/25° C	0.960	0.992
Flash point °C..	42	105
Burning point °C..	67	145
Viscosity, Engler, specific	[1] 152.4	[2] 9.0
Loss, 5 hours at 163° C., 20 grams per cent..	27.53	16.33
Float test on residue, 50° C. (time)	[3] 2′ 19″	[3] 2′ 40″
Percentage of total bitumen insoluble in 86° B. naphtha	10.40	10.83
Fixed carbon per cent..	5.01	5.82
Soluble in CS_2 (total bitumen) do....	99.94	99.94
Organic matter insoluble do....	.06	.04
Inorganic matter insoluble do....	.00	.02
Total do....	100.00	100.00

[1] At 25° C., 50 c.c. [2] At 100° C., 100 c.c. [3] Soft, sticky, with slight flow.

TABLE 2.—*Analysis of water-gas tar preparation used in experiments at Lemon City, Fla.*

	No. 1.		No. 2.	
Specific gravity 25 °/25°C	1.084		1.120	
Viscosity, Engler, 100 c.c., specific	[1] 13.3		[2] 24.5	
Free carbon per cent..	1.54		1.75	
	By volume.	By weight.	By volume.	By weight.
Distillation:				
Water per cent..	0.0	0.0	0.0	0.0
First light oils to 110° C do....	[3] .7	.5	[3] 1.0	.6
Second light oils (110°–170° C.) do....	[4] 1.1	.8	[3] .8	.5
Heavy oils (170°–270° C.) do....	[3] 34.6	31.1	[3] 20.4	17.5
Heavy oils (270°–315° C.) do....	[5] 14.1	12.5	[6] 13.4	11.7
Pitch residue do....	[7] 49.5	55.0	[8] 64.4	69.6
Total do....	100.0	99.9	100.0	99.9

[1] At 25° C.
[2] At 50° C.
[3] Clear.
[4] Cloudy.
[5] Clear, showed 15.0 per cent insoluble in dimethyl sulphate.
[6] Clear, showed 12.5 per cent insoluble in dimethyl sulphate.
[7] Hard, glossy. A 315°–350° C. fraction showed 17.5 per cent, and a 350°–375° C. fraction showed 12.5 per cent insoluble in dimethyl sulphate.
[8] Hard, glossy. A 315°–350° C. fraction showed 11.25 per cent, and a 350°–375° C. fraction showed 10 per cent insoluble in dimethyl sulphate.

EXPERIMENT NO. 1 (HEAVY OIL—PENETRATION METHOD).

Location: Station 0+00 to station 0+35.8=35.8 feet.
Area: 71.6 square yards.

Method.—It was attempted to produce a surface similar to that of experiment No. 6 at Miami, but with a heavier application of bituminous material. The conditions were adverse in the uneven texture of the surface caused by crushing under the roller, as mentioned above, and in the low temperature at which the bitumen had to be applied on account of its tendency to foam when heated. The application, though made evenly, puddled badly and produced, after the spreading of the sand, a rough mat. The bitumen was applied at an average rate of 1.26 gallons per square yard, and allowed to stand for about four hours, when it was covered with sand and rolled. This treatment, in general, appeared to be a failure.

EXPERIMENT NO. 2 (LIGHT OIL—PENETRATION METHOD).

Location: Station 0+35.8 to station 0+58.1=22.3 feet.
Area: 44.6 square yards.

Method.—This section was intended to be a part of experiment No. 1, but owing to the destruction of the barrel markings during storage, a kettle of the light oil was heated by mistake and applied here at an average rate of 1.12 gallons per square yard. It was entirely absorbed during a half hour's standing, after which it was covered with sand and rolled.

EXPERIMENT NO. 3 (HEAVY OIL—PENETRATION METHOD).

Location: Station 0+58.1 to station 1+65.9=107.8 feet.
Area: 215.6 square yards.

Method.—The apparent failure of experiment No. 1 necessitated a return to substantially the same method as was used in experiment No. 6 at Miami, although the poor working conditions did not promise equal success. The application of hot bitumen was reduced to an average rate of 0.89 gallon per square yard. From station 0+58.1 to station 1+39.0 the actual rate of application was 1.01 gallons per square yard. From station 1+39.0 to station 1+65.9 rains during the previous night had so bound the surface that the rate of application had to be reduced to 0.54 gallon per square yard, and little more than a surface treatment was obtained. The sand was applied and rolled as usual.

EXPERIMENT NO. 4 (WATER-GAS TAR PREPARATIONS—SURFACE TREATMENT).

Location: Station 1+65.9 to station 1+95.4=29.5 feet.
Area: 59 square yards.

Method.—Owing to the postponement of the work from January 13 to 29, this section of the road had become completely water bound by rains and heavy traffic. The surface was thoroughly swept with rattan brooms, and water-gas tar preparation No. 1 applied without heating at a rate of 0.25 gallon per square yard and allowed to stand for 24 hours. Water-gas tar preparation No. 2 was then applied at the rate of 0.42 gallon per square yard and allowed to stand for about four hours. By that time it appeared to have reached its maximum penetration and was covered with sand and rolled. By the use of the light tar preparation applied directly to the surface of the rock and followed by the heavier product, it was hoped to secure greater adherence of the bituminous surface than had previously been obtained in strict surface treatment, and at the same time build up a comparatively thick wearing coat.

EXPERIMENT NO. 5 (WATER-GAS TAR PREPARATION—PENETRATION METHOD).

Location: Station 1+95.4 to station 3+34.4=139 feet.
Area: 278 square yards.

Method.—The screened-rock course was constructed as usual, but by rescreening the rock the proportion of fine material was considerably reduced. Conditions were generally better than in the other experiments of the series. The bitumen (water-gas tar preparation No. 2) was heated to an average temperature of 90° C., and applied at an average rate of 1.08 gallons per square yard, covered with sand, and rolled.

EXPERIMENT NO. 6 (CALCIUM CHLORIDE).

In connection with the foregoing series of bituminous experiments, a section of ordinary coralline-rock surface was treated with an application of calcium chloride, which is a hygroscopic salt obtained as a by-product in the manufacture of soda by the Solvay process. No record of the cost of this work was obtained.

The coralline-rock road is at its best when slightly wet or moist, and its rapid wear occurs when dry. It was hoped, therefore, that the application of a hygroscopic salt in this area bordering on the ocean would have the effect of keeping the surface damp, thus securing a serviceable and lasting condition.

Seven drums of calcium chloride, each weighing 350 pounds net, were furnished by the manufacturer. Five of these drums were used, the remaining two being reserved for a second application to the center of the roadway when necessary. The section which was treated on January 28, 1914, lies immediately north of experiment No. 1 and is 590 feet long and 18 feet wide, containing an area of 1,175 square yards. The rate of application was 1.49 pounds per square yard, heavy in the center and light on the extreme sides. The material came from the drums in a lumpy condition and was difficult to spread evenly. After several weeks of wear the surface was damp at all times, but pitted to some extent, showing bare rock in spots.

SUMMARY OF EXPERIMENTS AT LEMON CITY, FLA.

When inspected, on January 16, 1915, none of the experiments on which bituminous materials were used showed any decided evidence of failure. No. 1 appeared to be in slightly better condition than No. 3, on which the same heated oil had been used. It was fairly smooth, had a good cross section, and the bitumen still possessed life.

Experiment No. 2, where the light oil was used, was in good condition, but the bitumen had a brownish, dead appearance, and the individual rock particles showed throughout the section.

Experiment No. 4, which received the double surface treatment, showed a fine-grained mosaic surface with a few incipient potholes. It had not worn appreciably below the adjacent section.

Experiment No. 5 had a perfect mosaic surface, with slight indentations around the individual particles of stone. The bitumen had become quite hard, and the section should be given a light surface treatment at an early date. One depression was noted in this experiment, on the west side, at the joint about 55 feet from the south end.

The materials and cost data for these experiments are shown in the following table:

TABLE 3.—*Materials and cost data for experiments at Lemon City, Fla., 1914.*

Experiment No.	Materials.	Description.			Quantities of materials per square yard.			Cost per square yard (cents).								
		Method.	Length of section (feet).	Area of section (square yards).	New rock (cubic yards).	Bitumen (gallons).	Sand (cubic yards).	Preparing subgrade.	Shoulders.	New rock in place.	Bitumen.[2]	Hauling bitumen.	Sand.	Heating and applying bitumen.	Rolling and finishing.	Total cost.
1	Heavy oil	Penetration	35.8	71.6	0.103	1.26	0.014	0.10	2.25	25.86	16.88	2.40	3.25	2.60	2.90	56.24
2	Light oil	do	22.3	44.6	.103	1.12	.014	.10	2.25	25.86	12.77	2.10	3.25	2.30	2.90	51.53
3	Heavy oil	do	107.3	215.6	.103	.89	.014	.10	2.25	25.86	11.93	1.70	3.25	1.90	2.90	49.89
4	Water-gas tar preparation.	Surface treatment.	29.5	59.0	.103	[1] .67	.014	.10	2.25	25.86	7.84	1.30	3.25	1.40	2.90	44.90
5	do	Penetration	139.0	278.0	.103	1.08	.014	.10	2.25	25.86	12.66	2.00	3.25	2.20	2.90	51.22

[1] Includes both applications.

[2] Bitumen cost based on quotations for tank-car lots.

EXPERIMENTS AT WEST PALM BEACH, FLA.

OIL, TAR, OIL-ASPHALT, CORALLINE ROCK.

These experiments, located on the Miami-Quebec highway, about 2 miles south of West Palm Beach, were constructed in April and May, 1914, by Palm Beach County, under the direction of the Office of Public Roads. The purpose was to develop a more economical and durable road surface than is obtainable by the use of coralline rock under ordinary methods of construction.

There are in this county about 150 miles of hard-surface roads. The material used exclusively for this surfacing is a soft, oölitic limestone known as coralline rock, or locally as simply ''rock.'' It is obtained from two pits in Dade County, which borders Palm Beach County on the south. One of these pits, located at Fort Lauderdale, furnishes a coralline rock which is softer than the average and contains a considerable proportion of sand. For ordinary construction, it has given apparently satisfactory results. The rock quarried from the other pit, located at Ojus, is blasted and excavated from under water. It is comparatively hard and contains a relatively small amount of fine material. It was therefore chosen as the more suitable of the two for bituminous construction, and used in the experiments.

The experience gained from the construction of the experiments at Miami[1] and from their inspection after long usage by traffic showed conclusively that the best method of treatment involved the use of rock from which the finer particles had been removed to provide for uniform penetration of the bitumen. The experiments at West Palm Beach were therefore all constructed on this basic principle. The general method of construction preparatory to the application of the bitumen was, in brief, as follows:

The preparation of a thoroughly compacted subgrade parallel to the finished surface and composed of the rock originally in the roadbed; upon this, a course of screened rock with a uniform loose depth of 3 inches, lightly compacted to allow a maximum penetration of bituminous material.

The screened rock used was produced at great disadvantage and consequently high cost. Furthermore, in addition to screening out the material below one-half inch in size, it would have been desirable, if practicable, to screen out all above 2½ inches. These larger sizes had to be picked out by hand by the rakeman on the screen and by the spreaders on the road. In any large-scale future work, a small crushing plant, elevator, revolving screens, and bins should be installed, preferably at the quarry. All rock was spread by shoveling back from piles dumped a little in advance of the work.

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[1] Bulletin of the U. S. Department of Agriculture No. 105.

The sand used, from which roots and grass were removed by the use of a ⅜-inch screen, was a clean, white silica obtained at the roadside.

Dustless screenings, so-called, were obtained by rescreening on a ¼-inch screen all rock that had passed the ½-inch screen. All material passing the ¼-inch mesh was classed as "extra fines." About 33 per cent of the rock passed the ½-inch screen, of which one-half was recovered on the ¼-inch screen. There was no appreciable change in volume between the pit run and the screened rock above one-half inch.

It was found necessary to extend the width of the subgrade from 12 feet to 15 feet on account of the thin depth of the original rock outside the former width. This was done by trenching the sides and backfilling with sufficient rock to give the required grade. About 15 per cent of the total cost of the work was expended in this manner.

EXPERIMENT NO. 1 (RESIDUAL ASPHALTIC PETROLEUM—PENETRATION METHOD).

Location: Station 0+00 to station 1+02=102 feet.
Area: 170 square yards.

TABLE 4.—*Analysis of residual asphaltic petroleum.*

Specific gravity 25°/25° C.		0.989
Flash point	°C.	130
Burning point	°C.	155
Viscosity, Engler, 100 c. c. at 100° C., specific		9.8
Float test at 32° C. (time)		44″
Float test at 50° C. (time)		27″
Loss, 5 hours at 163° C., 20 grams	per cent.	13.74
Float test on residue at 32° C. (time)		7′ 49″
Float test on residue at 50° C. (time)		2′ 0″
Percentage of total bitumen insoluble in 86° B. naphtha		10.05
Fixed carbon	per cent.	4.68
Soluble in CS_2 (total bitumen)	do.	99.92
Organic matter insoluble	do.	.05
Inorganic matter insoluble	do.	.03
Total		100.00

Method.—The screened-rock course was lightly rolled to bring the surface to a smooth cross section and leave an open surface which would allow deep penetration of the bitumen. The rate of application for the penetration course was 1.76 gallons per square yard, at an average temperature of 95° C. No excess of bitumen remained on the surface, which was then covered with sand and thoroughly rolled. Before applying the seal coat all free sand was swept from the surface with rattan brooms. The rate of application of the seal coat was 0.56 gallon per square yard. A top dressing of sand was applied and the surface thoroughly rolled.

A. From stations, 0+00 to 0+50, the seal-coat application was allowed to stand two hours before sanding.

B. From stations, 0 + 50 to 1 + 02, approaching rains necessitated the sanding of the seal coat immediately after application. This caused a marked difference in the resulting surface condition of portions A and B of the experiment. The mat on the latter contained an excess of bitumen, and more sand had to be added from time to time until a thick, mushy top was formed. About a month after construction this mat was removed, heated, and respread to a thickness of about one-quarter of an inch.

The bituminous material used in this experiment was found to contain a small percentage of water, probably due to seepage through the barrels during transit. In heating, when the temperature reached the boiling point of water, the material foamed so excessively as to cause overflowing from the kettles. It was necessary, therefore, to apply the oil at a temperature of about 95° C., which was lower than desirable for best results and caused the rate of application to be greater than necessary. It was also found that the top voids, although assisting in securing excellent penetration, were too large to assure good results when filled with sand dressing.

EXPERIMENT NO. 2 (REFINED COAL TARS—PENETRATION METHOD).

Location: Station 1+02 to station 1+94=92 feet.
Area: 153.3 square yards.

TABLE 5.—*Analyses of refined coal tars.*

	Lot No. 1.		Lot No. 2.	
Specific gravity 25°/25° C.	1.288		1.282	
Float test at 50° C. (time)	4′ 18″		3′ 33″	
Free carbon, per cent	29.61		28.30	
	By volume.	By weight.	By volume.	By weight.
Distillation:				
Water, per cent	0.0	0.0	0.0	0.0
First light oils to 110° C., do.	[1].1	.1	[2].4	.2
Second light oils (110°–170° C.), do.	[2].6	.4	[2].3	.4
Heavy oils (170°–270° C.), do.	[3]3.8	3.0	[3]4.4	3.4
Heavy oils (270°–315° C.), do.	[4]11.5	9.4	[5]11.4	9.0
Pitch residue, do.	[6]84.0	87.1	[6]83.5	86.8
Total	100.0	100.0	100.0	99.8

[1] One-half solid.
[2] Solid.
[3] Cloudy.
[4] One-eighth solid.
[5] One-fifth solid.
[6] Hard, dull, brittle.

Method.—The rock course was rolled more heavily to reduce the voids below the percentage obtaining in experiment No. 1. The heavy refined tar, designated as lot No. 1, was then applied at the rate of 0.98 gallon per square yard. The average temperature of the tar was 175° C. The rock was dry and hot from the sun, the tar flowed readily and, after standing a few minutes, entirely penetrated into the rock course. Sand was then applied and swept into the voids. The sand dressing, however, while filling the voids, did not incorporate with the bitumen, but remained for the most part dry and loose. The individual tar-coated rock particles were left projecting and unprotected and would have worn away rapidly under traffic. All free sand was therefore swept from the surface, and a light coal tar was applied cold at the rate of 0.33 gallon per square yard and allowed to stand for about four hours until completely absorbed. The surface was then covered with sand and thoroughly rolled. The sample of the light tar was lost in shipment, and consequently no analysis is given.

EXPERIMENT NO. 3 (REFINED COAL TAR—PENETRATION METHOD).

Location: Station 1+94 to station 3+68.8=174.8 feet.
Area: 291.5 square yards.
Material: Refined coal tars, analyses of which are given in Table 5.

Method.—The general nature of this experiment is the same as that of the preceding, except for the omission of a second application of bituminous material and the use of dustless screenings instead of sand. From station 3+25 to the end of the next experiment heavy rains had so bonded the rock surface that it had to be harrowed, regraded, and rolled in order to provide for suitable penetration. The smoothness of the original cross section could not be restored, and the surface of this portion of the road remains slightly irregular. The application of bituminous material was made at the rate of 1.20 gallons per square yard, and was immediately covered with dustless screenings, filling the voids and thinly covering the surface, which was then thoroughly rolled. The screenings crushed somewhat under the roller, but seemed to absorb the bituminous material and form a firm, rigid surface.

Tar of lot No. 1 was used from station 1+94 to station 2+76. From the latter point to the end of the section material from a second shipment, designated in Table 5 as lot No. 2, was used. This material did not flow and penetrate as satisfactorily as lot No. 1, even when heated to 185° C.

EXPERIMENT NO. 4 (RESIDUAL ASPHALTIC PETROLEUM—PENETRATION METHOD).

Location: Station 3+68.8 to station 5+84=215.2 feet.
Area: 358.6 square yards.

TABLE 6.—*Analysis of residual asphaltic petroleum.*

Specific gravity, 25°/25° C.	0.980
Flash point °C.	125
Burning point °C.	143
Viscosity, Engler, 100 c. c. at 100° C., specific	5.5

Float test at 32° C. (time)		22″
Float test at 50° C. (time)		14″
Loss, 5 hours at 163° C., 20 grams	per cent..	16.82
Float test on residue at 32° C. (time)		6′ 30″
Float test on residue at 50° C. (time)		1′ 46″
Percentage of total bitumen insoluble in 86° B. naphtha		9.37
Fixed carbon	per cent..	4.64
Soluble in CS_2 (total bitumen)	do....	99.87
Organic matter insoluble	do....	.05
Inorganic matter insoluble	do....	.08
Total	do....	100.00

Method.—The rock course was rolled until firm, after which dustless screenings were scattered lightly over the rock surface, partly filling the larger voids. The rate of application of the bitumen was 1.39 gallons per square yard at an average temperature of 105° C. The bitumen flowed readily and penetrated completely when allowed to stand for a sufficient time. Frequent rains during the treatment of this section handicapped the performance of the work and at times necessitated sanding immediately after the application of the bitumen.

A. From stations 3 + 68.8 to 5 + 15.5, sand was used as a top dressing. This section bled profusely and unevenly for about two weeks after construction, forming a sand mat of uneven thickness. In those areas where there was no bleeding the surface had a light brown color and the bitumen seemed to have become somewhat absorbed in the rock itself. Traffic was permitted the use of this portion of the experiment immediately after construction.

B. From stations 5 + 15.5 to 5 + 84, dustless screenings were used as top dressing and there was no bleeding over this area. Traffic did not use this section until three weeks after construction.

EXPERIMENT NO. 5 (OIL-ASPHALT—PENETRATION METHOD).

Location: Station 5+84 to station 6+32=48 feet.
Area: 80 square yards.

TABLE 7.—*Analysis of oil-asphalt.*

Specific gravity, 25°/25° C.		1.008
Melting point	°C..	58
Penetration, 25° C., 100 grams, 5 seconds	m. m..	10.2
Loss, 5 hours at 163° C., 20 grams	per cent..	.44
Penetration of residue, as above		7.9
Percentage of total bitumen insoluble in 86° B. naphtha		23.97
Fixed carbon	per cent..	11.06
Soluble in CS_2 (total bitumen)	do....	99.86
Organic matter insoluble	do....	.10
Inorganic matter insoluble	do....	.04
Total	do....	100.00

Method.—The work on the experimental road was discontinued from April 16 to May 18, owing to delay in the arrival of the oil asphalt. During this time heavy rains had rendered the prepared rock surface unfit for penetration work, and it was therefore harrowed, regraded, and rolled to proper condition from station 5+84 to station 8+60. The larger voids were partly filled with dustless screenings. The rate of application of bituminous material was 1.75 gallons per square yard, and the average temperature was 175° C. The penetration was not good, owing to the rapid congealing of the oil asphalt on a dense surface of this type. The top dressing of dustless screenings was immediately applied in sufficient quantity to fill the voids and thinly cover the surface, which was then thoroughly rolled.

EXPERIMENT NO. 6 (OIL ASPHALT—PENETRATION METHOD).

Location: Station 6+32 to station 7+17=85 feet.
Area: 141.6 square yards.
Material: Oil asphalt, analysis of which is shown in Table 7.

Method.—The rock course was compacted with a rather heavy rolling. An application of oil asphalt was made at the rate of 1.52 gallons per square yard and at an average temperature of 185° C. This was immediately covered with sand. As in experiment No. 2, the sand did not become incorporated with the bitumen, but remained to a large extent dry and loose. All free sand was swept entirely off the road, and a sand-asphalt mixture was spread upon the penetration course. This was composed of 1 cubic foot of roadside sand to 1 gallon of oil asphalt, both at a temperature of 175° C. The mixture filled the interstices and formed a wearing surface about one-quarter of an inch thick above the topmost particles of the rock. It bonded with the lower course both by irregularities in the latter and by reason of the melting of the first bituminous coat through contact with the hot mixture.

EXPERIMENT NO. 7 (WATER-BOUND MACADAM).

Location: Station 7+17 to station 8+60=143 feet.
Area: 238.3 square yards.

Method.—As in the previous experiments, the subgrade was prepared and compacted parallel to the cross section of the finished road, and a course of screened rock spread to a uniform depth of 3 inches. This was heavily rolled until there was no visible yielding under the roller. No material was available from the first screening through a ½-inch screen. Dustless screenings and dust were therefore mixed in equal parts and spread over the surface, after which the roadway was flushed with water and thoroughly rolled.

One purpose of this experiment was to provide a basis of comparison between the various bituminous treatments and a well-constructed coralline-rock road. Another and more important one was to demonstrate, if possible, that the principal defect in the existing roads, the rapid development of an uneven surface, could be overcome by proper methods of construction. By the method here used a surface of uniform strength is secured by reason of the uniform strength of the subgrade and the uniform depth and consistency of the screened-rock course. Such uniformity can be obtained in no other way, apparently, than by screening the rock and following the general method of construction used in this experiment.

In the cost data, which follow, the cost of bituminous materials was taken from bid prices for carload lots.

TABLE No. 8.—*Materials and cost data for experiments at West Palm Beach, Fla., 1914.*

Experiment No.	Materials.	Description.		Quantities of materials per square yard.					Cost per square yard (cents).											
		Length of section (feet).	Area of section (square yards).	New rock (cubic yards).	Bituminous material, first application (gallons).	Bituminous material, second application (gallons).	Rock screenings (cubic yards).	Sand (cubic yards).	Extending width.	Preparing subgrade.	New rock in place.	Bituminous material.	Sand or screenings.	Spreading sand or screenings.	Heating, mixing, and applying bituminous-sand mat.	Sprinkling.	Rolling and finishing.	Miscellaneous.	General charges.[1]	Total.
1	Residual asphaltic petroleum	102.0	170.0	0.083	1.76	0.56	....	0.021	8.52	4.57	23.94	27.84	0.54	0.50	......	......	1.46	3.50	3.32	74.19
2	Refined coal tars	92.0	153.3	.083	.98	.33	....	.021	8.52	4.57	23.94	11.95	.54	.50	......	......	1.46	3.50	3.32	58.32
3	Refined coal tar	174.8	291.5	.083	1.20	....	0.014	....	8.52	4.57	23.94	11.40	2.25	.30	......	......	1.46	3.50	3.32	58.26
4	Residual asphaltic petroleum	215.2	358.6	.083	1.39	....	.004	.010	8.52	4.57	23.94	16.68	.90	.30	......	......	1.46	3.50	3.32	63.19
5	Oil-asphalt	48.0	80.0	.083	1.75	....	.014	....	8.52	4.57	23.94	19.69	2.25	.30	......	......	1.46	3.50	3.32	67.55
6	.....do	85.0	141.6	.083	1.52	.30	....	.021	8.52	4.57	23.94	20.47	.54	.50	9.46	......	1.46	3.50	3.32	76.28
7	Water-bound macadam	143.0	238.3	.083	....	....	.028	....	8.52	4.57	23.94	......	4.51	.60	......	0.60	1.46	3.50	3.32	51.02

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[1] Includes rental of kettles, supplies, hauling, oil, etc.

SUMMARY OF EXPERIMENTS AT WEST PALM BEACH, FLA.

These experiments were carefully inspected on January 20, 1915, and their general condition reported upon as follows:

Experiment No. 1.—The surface of this experiment throughout is in uniformly good condition. The bitumen is still lively and possesses, to a certain extent, its original characteristic odor. The flow of the excessive bitumen is noticeable here and there along the side of the road, but there are no waves or irregularities that would be apparent to traffic.

Experiment No. 2.—The general character of this experiment is about the same as that of No. 1, except for its darker color and the fact that the bituminous material has become very hard and brittle.

Experiment No. 3.—The tar used in this experiment has become hard and friable. The excess present in the original construction, as well as the top dressing of fine rock, has disappeared. The surface has worn almost uniformly to a perfect mosaic or terrazzo appearance, and the large particles of soft rock now exposed are wearing very rapidly. A surface treatment will therefore be applied before any serious wear occurs.

Experiment No. 4.—This section, while it is in good condition and free from any wearing defects, presents a varied appearance. Where sand was used there are places which bear a close resemblance to experiment No. 1, while other areas show a mosaic appearance due to the wearing of the rock in the wearing course. These differences are undoubtedly due to the varied weather conditions under which the experiment was constructed.

Where rock screenings were used the surface is much lighter and somewhat mottled, and evidently more susceptible to wear than the sanded surface.

Experiment No. 5.—This experiment has a mottled appearance due to the fact that the bitumen has bled to the surface and formed a mat over some areas, while the rock is exposed to wear in others. The bituminous material is still lively.

Experiment No. 6.—This experiment is reported as having been somewhat soft and sticky during the summer of 1914, but at the time of this inspection it was in excellent condition and presented a smooth surface true to the original cross section.

Experiment No. 7.—This experiment offers an excellent example of the relative wear of water-bound coralline rock as compared with the bituminous-bound. The surface is smooth, unbroken, and true to cross section, but measurements made where it joins the adjacent bituminous-bound section indicate that the water-bound macadam has worn down about seven-eighths of an inch below the adjacent bituminous-bound section.

The following table shows the results of a traffic census taken between 6 in the morning and 12 midnight on three successive days in January, 1915.

TABLE 9.—*Volume and character of traffic over experiments at West Palm Beach, Fla., on three successive days in January, 1915.*

Vehicles.	Saturday, Jan. 23.[1]		Sunday, Jan. 24.[2]		Monday, Jan. 25.[3]		Average per day.
	North-bound.	South-bound.	North-bound.	South-bound.	North-bound.	South-bound.	
Loaded 1-horse wagons	7	6	2	1	3	7	8.7
Unloaded 1-horse wagons	4	4	1	3	7	7	8.7
Loaded 2-horse wagons	5	2	1	1	5	0	4.7
Unloaded 2-horse wagons	4	2	0	0	1	4	3.7
1-horse pleasure vehicles	3	4	1	2	2	2	4.7
Motor cycles	15	19	12	10	16	15	29.0
Motor runabouts	11	14	0	3	8	14	13.3
Motor touring cars	127	114	82	84	97	102	202.0
Loaded motor trucks	1	2	0	0	1	3	2.3
Unloaded motor trucks	1	1	1	1	3	0	2.3
Bicycles	101	141	49	65	118	130	201.3

[1] Heavy rain morning and evening; showers all day.
[2] Heavy rain 6 to 7 a. m., 12 to 6 p. m.; showers balance of day.
[3] Heavy rain 10 a. m. to 1 p. m.; showers balance of day.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT MIAMI, FLA., 1913.

OIL-CORALLINE ROCK.

The original report of these experiments will be found in U. S. Department of Agriculture Bulletin No. 105. When inspected and repaired on January 29, 1914, the surface treatment in experiments Nos. 1 and 2 had worn so badly that repairs were out of the question. It had broken through in a number of places, exposing the soft underlying rock to excessive wear, and this finally resulted in such a rough and objectionable surface that both sections were later scarified, regraded, and rolled without further treatment. The remaining experimental sections were repaired where necessary by patching all holes and breaks in the surface in the following manner:

The surface was cut away around the affected areas to form holes about 4 inches deep, with straight, sharp edges. These were filled with a thorough mixture of pit-run rock and the light-oil product, with care to use only sufficient oil to coat all the particles. The mixture was tamped in place in layers about 1 inch thick. The following table shows the extent and cost of these repairs:

TABLE 10.—*Cost of repairs to experiments at Miami, Fla.*

Experiment No.	Area of patches (square feet).	Cost.	Cost per square yard.
3	0	$0.00	$0.000
4	3	.89	.002
5	24	7.17	.013
6	0	.00	.000

The following report covers the condition of the existing experiments on January 16, 1915:

Experiment No. 3 (Penetration Method—Hot, Heavy Oil).

This experiment remains in fairly good condition, although it has worn to a somewhat rough and uneven cross section. No breaks have occurred, however, and only one worn depression was noted.

Experiment No. 4 (Penetration Method—Cold, Light Oil).

This experiment continues in fair condition, although it does not present as good an appearance as No. 3. A group of small worn places were noted just north of the middle of the section.

Experiment No. 5 (Penetration Method—Hot, Heavy Oil).

This is decidedly the poorest of the remaining sections, and apparently demonstrates the lack of economy in reducing the wearing course of rock to less than 2½ inches of uncompacted material. Seventeen worn depressions, ranging from one-half square foot to 2 square feet in area were distributed throughout the section, and it was apparent that they had been brought to grade by filling with coralline rock. These will be patched with bituminous material and rock.

Experiment No. 6 (Penetration Method—Hot, Heavy Oil).

This experiment continues in excellent condition after having been under rather heavy traffic for over 18 months, and is a successful demonstration of what can be accomplished in this form of construction. The bitumen has flowed in a couple of places and is still lively, but the cross section is well preserved, and there is no evidence of excessive wear.

SUPPLEMENTARY REPORT OF EXPERIMENTS ON ROCKVILLE PIKE, MARYLAND, 1913.

The original report of these experiments was given in U. S. Department of Agriculture Bulletin No. 105, and the following information covers their history to and including an inspection on February 9, 1915.

Experiment No. 1 (Refined Coal Tar—Hot Application).

This experiment has shown somewhat marked fraying along the edges, and a very noticeable deterioration of a strip along one edge for about 400 feet where trees overhang the road. The underlying macadam is fast becoming exposed over fairly large areas, and at the time of inspection it appeared probable that the restoration of the mat will be necessary early in the spring of 1915. One single-track trolley crossing has somewhat increased the surface-repair costs. No repairs, however, have been large in size. The experiment is in generally good condition except for the uniform wear, and it is free from holes or weak spots.

The part of this experiment in Bradley Lane is suffering severely by reason of the very heavy traffic in both directions. The frequent passing compels practically every vehicle to run off the metal at some point, and the continual wear at the edges has reduced the effective width and caused damage that can not be satisfactorily repaired short of reconstruction. This is an obvious case of the traffic being too heavy for a single-line road.

EXPERIMENT NO. 2 (REFINED WATER-GAS TAR—COLD APPLICATION).

In the early summer of 1914 the surface of this experiment began to fail so rapidly through numerous breaks in the mat that it became practically impossible to prevent total failure by means of patrol maintenance. The failure seemed more pronounced over that portion of the experiment where gravel had been used, and this is attributed to the fact that the gravel was coarser than it should have been.

Therefore, between June 29 and July 3 a second treatment was applied. Refined water-gas tar purchased under the specification for the original treatment was used, and the application was made by means of an automobile pressure distributor. The tar was brought directly from the stills of the manufacturer and applied at a temperature of 150° to 175° F. Clean trap-rock chips and ⅜-inch gravel were used as a covering material, each over the same parts of the experiment where it had been originally used. The characteristics of the bituminous material are given in the following table, and the cost data will be found at the end of this supplementary report.

TABLE 11.—*Analysis of refined water-gas tar.*

Specific gravity 25°/25° C.		1.123
Viscosity, Engler, 50 c. c. at 50° C., specific		27.0
Free carbon	per cent	0.80

Distillation:		By volume.	By weight.
Water	per cent	0.0	0.0
First light oils to 110° C.	do	[1] .1	.1
Second light oils (110°–170° C.)	do	[1] .6	.5
Heavy oils (170°–270° C.)	do	[2] 26.5	23.4
Heavy oils (270°–315° C.)	do	[2] 13.8	12.5
Pitch residue	do	[3] 59.0	63.4
Total	do	100.0	99.9

This surface is now fully as good, if not better, than at the time of original construction. There are two sections of surface, near Norwood trolley station and south of Edgewood station, where the original construction left the road flat and inadequately drained. These are now showing the strain of more or less continued dampness from underneath. The gravel section of this experiment has a markedly better appearance than the trap section.

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[1] Trace solid.

[2] One-fourth solid.

[3] Fairly hard and glossy.

The surface of experiment No. 2 in Bradley Lane is in fairly good condition and free from bad holes or depressions.

EXPERIMENT NO. 3 (ASPHALTIC PETROLEUM—COLD APPLICATION).

The surface of this experiment also began to fail rapidly during the summer of 1914, and the failure seemed most pronounced at first on the section where rather coarse gravel had been used for a covering material. Moreover, during the winter of 1913–14, not only was the surface cut through because of culvert repairs, but several rather large areas heaved as a result of frost action. This latter damage was due to the partial burning out of some of the surfacing bitumen by bonfires set along the outer edge of the road. In a few places along the sides of the road the surface mat had cracked to some extent.

A new treatment was therefore applied between September 23 and 27, in which the same grade and character of oil as that originally applied was used. The application was made by permitting the oil to run from the bung of the barrel and sweeping it over the surface with rattan push brooms. From station 135 + 00 to station 144 + 00, where the original surface was still fairly smooth and intact, the application was at the rate of 0.13 gallon per square yard, while over the remainder of the experiment it was at the rate of 0.18 gallon per square yard. The average was 0.176 gallon per square yard. The application was immediately covered with clean torpedo sand.

Table No. 12 shows the characteristics of the bituminous material used, and the cost data will be found at the end of this supplementary report.

TABLE 12.—*Analysis of asphaltic petroleum.*

Specific gravity 25°/25° C		0.932
Flash point	°C	35
Burning point	°C	70
Viscosity, Engler, 50 c. c. at 25° C., specific		61.9
Loss, 5 hours at 163° C., 20 grams	per cent	22.94
Float test of residue at 32° C. (time)		5′ 53″
Float test of residue at 50° C. (time)		1′ 22″
Percentage of total bitumen insoluble in 86° B. naphtha		13.67
Fixed carbon	per cent	7.62
Soluble in CS_2 (total bitumen)	do	99.90
Organic matter insoluble	do	.10
Inorganic matter insoluble	do	.00
Total	do	100.00

At the date of inspection this experiment was in essentially as good condition as at the time of construction. The surface was noticeably better on the gravel half of the section and had a corky feeling to the tread throughout. In wet weather the surface has become somewhat muddy, especially in the bottoms, and this action appears characteristic of all the experimental surfaces treated with petroleum products.

In deducing maintenance costs for this section, proper allowance has been made by excluding the cost of subsurface repairs not due to failure of the surface treatment.

EXPERIMENT NO. 4 (RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION).

This experiment presented probably the best appearance of any of the original construction at the time of last inspection. During the winter of 1913–14 its surface remained practically intact, but in the winter of 1914–15 it cracked in a few places and became slightly muddy. The muddy condition rapidly disappears in dry weather and a smooth leathery surface results.

The surface has had about the same amount of attention as that of experiment No. 1, and will probably not require a general re-treatment during the coming season. This experiment, together with No. 5 and No. 6, all of which were given hot surface treatments, required considerable top-dressing during the first warm days of spring to stop further bleeding. The surface still has a few humps in spots where the distributor leaked at the time of spreading the bitumen. Many of these humps have been cut down with a mattock or hot shovel, but all are not yet entirely removed, because their tendency to bleed and consequent addition of top-dressing tend to build them up again. Three or four potholes were noted, and at one place on the east side of the road there appears to be a stripped track that has developed since the late fall of 1914. This may have been a long repair made at the time of construction after an automobile ran over the section before top-dressing was spread. Along this strip, some 500 or 600 feet in length, and between it and the edge of the surface the underlying macadam is generally bare, but is not raveling.

EXPERIMENT NO. 5 (RESIDUAL ASPHALTIC PETROLEUM—HOT APPLICATION).

The surface shows a tendency to crack in cold weather, and in wet weather works into a mud more readily than the surface of experiment No. 4. Like experiment No. 4, the surface is soon ironed into a smooth, leathery mat when dry weather permits. During the year the cost of surface work has been greater than on No. 1 or No. 4. It was also slightly higher than on No. 6. The hilltop at the north end of the experiment is better than elsewhere, probably on account of more thorough subdrainage. Any areas poorly drained are at once noticeable through this surface.

EXPERIMENT No. 6. (WATER-GAS TAR PREPARATION—HOT APPLICATION).

This experiment bled rather freely in the spring and required considerable top-dressing and repairs, especially on the trap section. The surface does not become muddy, although dampness shows through along several areas where subdrainage is poor. Most of the repairs so far have been due to some little stripping of the bitumen that occurred early in the spring before top-dressing could be applied. Such repairs have, however, been few, and less bitumen has been required than on any of the other experiments.

EXPERIMENT No. 7 (ASPHALTIC PETROLEUM—COLD APPLICATION).

The surface of this experiment worked into a rather objectionable muddy condition as soon as the winter of 1913–14 brought continued wet weather and frost. In the spring it ironed out and presented a very satisfactory appearance until about September. At this time numerous small weaknesses began to develop which, owing to cold weather, could not all be repaired before winter. Nevertheless, the surface has not become so muddy this winter (1914–15) as last, but the mud which is formed is in some spots a lighter brown color, indicating that the oil is losing its effect. This experiment is expected to require re-treatment at the earliest possible time in the spring, and may require considerable patching, as indicated by the rapidly increasing breaks in the surface during the late fall of 1914.

TABLE 13.—*Materials and cost data for renewal treatments of experiments Nos. 2 and 3 Rockville Pike, Maryland, 1914.*

	Experiment No. 2.		Experiment No. 3.
	Trap.	Gravel.	Torpedo sand.
Length ..... feet	4,330	3,050	7,400
Area ..... square yards	7,216.6	5,083.4	12,333
Bituminous material, per square yard ..... gallons	.294	.294	.176
Covering material, per square yard ..... cubic yards	.012	.012	.009
Cost (cents per square yard):			
Sweeping surface	(1)	(1)	0.048
Bituminous material	2.79	2.79	1.234
Applying bituminous material	(1)	(1)	.393
Covering material	4.39	2.52	1.994
Spreading covering material	.53	.53	.197
Total cost	7.71	5.84	3.866

[1] Automobile distributor used; sweeping and applying included in cost of material.

A traffic census on the Rockville Pike is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between January 1, 1914, and January 1, 1915, is given in Table 14.

TABLE 14.—*Volume and character of traffic on Rockville Pike at its intersection with Bradley Lane.*

Vehicle.	Maximum.		Average.	
	North-bound.	South-bound.	North-bound.	South-bound.
Loaded 1-horse wagon	25	23	13	13
Unloaded 1-horse wagon	26	26	12	11
Loaded 2-horse wagon	31	71	13	27
Unloaded 2-horse wagon	59	14	20	6
Loaded 4-horse wagon	4	4	1	1
Unloaded 4-horse wagon	5	3	1	0
1-horse pleasure vehicle	22	24	12	14
2-horse pleasure vehicle	5	5	1	2
Rubber-tired horse vehicle	3	2	0	0
Saddle horse	18	19	5	5
Motor cycle	39	35	20	18
Excessively heavy vehicle	12	18	3	4
Motor runabout	98	91	42	42
Motor touring car	243	187	96	89
Loaded motor dray	24	38	12	16
Unloaded motor dray	29	12	7	5

The total cost of maintenance and cost to date of each experiment are shown in the following table:

TABLE 15.—*Maintenance cost of experiments on Rockville Pike, Maryland, to December 31, 1914.*

Experiment No.	Bituminous material.	Date completed.	Length (feet).	Cost[1] per square yard (cents).	Surface[2] maintenance per square yard (cents).	Total cost of surface per square yard to Dec. 31, 1914.	Surface maintenance per mile for 1 year.	Total maintenance per mile for 1 year.
		1913.						
1	Refined coal tar (hot)	Sept. 22	6,105	12.34	1.58	13.92	$139.04	$332.93
2	Refined water-gas tar (cold)	Sept. 24	7,380	9.55	7.56	17.11	665.28	739.11
3	Asphaltic petroleum (cold)	Sept. 30	7,400	9.05	6.00	15.05	528.00	576.26
4	Residual asphaltic petroleum (hot)	Oct. 15	7,100	11.28	1.61	12.89	141.68	215.18
5	Do	Nov. 21	6,775	11.30	2.00	13.30	176.00	237.37
6	Water-gas tar preparation (hot)	Nov. 26	6,325	11.71	1.88	13.59	165.44	219.47
7	Asphaltic petroleum (cold)	Dec. 5	6,689	10.03	.71	10.74	62.48	106.82

[1] Average for trap and gravel.

[2] To Dec. 31, 1914.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT WASHINGTON, D. C., 1912.

TAR PREPARATIONS AND OILS—SURFACE TREATMENT.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads, and the inspection report for the first year was given in U. S. Department of Agriculture Bulletin No. 105. The following report gives the extent of the repairs during 1914 and the condition of the experiments when inspected on March 11, 1915:

All four sections in the summer of 1914 showed considerable wear. The surface mat of section No. 1 apparently was becoming somewhat brittle, especially along the sides of the road, although the treatment still remained generally intact. Section No. 2 had developed several holes of considerable area, but otherwise the surface was in excellent condition. Section No. 3 had several small holes, and the surface mat was largely worn off. The surface of section No. 4 was smooth and regular, but the large stones of the macadam were generally showing. The only repair necessary in this section was a water-bound patch approximately 6 square yards in area on the northwest side of the curve leading toward Twelfth Street, where there is practically no traffic.

In addition to this large patch, others of water-bound macadam were placed in sections 2 and 3. The total area of such patches was about 11 square yards.

The sections were then swept with hand brooms and given a surface treatment of the same type of bituminous material as that originally used, and covered with a fine torpedo sand. Some bituminous material had remained from the previous treatment, as follows: 130 gallons of residual petroleum for section No. 3, which was sufficient to treat the entire section, and 50 gallons of water-gas tar preparation, which was used on the south end of section No. 1.

Application of the bituminous material was accomplished by allowing it to run from the bungs of the barrels or drums directly upon the road and distributing it with push brooms. It was covered immediately with sand.

Analyses of additional materials purchased for this work are given in the following tables:

Table 15.—*Mechanical analysis of sand used in surface treatment at Washington, D. C., 1914.*

Retained on ⅛-inch screen	per cent	11.8
Passing ⅛-inch screen, retained on 10-mesh sieve	do	6.7
Passing 10-mesh sieve, retained on 20-mesh sieve	do	17.9
Passing 20-mesh sieve, retained on 30-mesh sieve	do	9.3
Passing 30-mesh sieve, retained on 40-mesh sieve	do	12.3
Passing 40-mesh sieve, retained on 50-mesh sieve	do	10.9
Passing 50-mesh sieve, retained on 80-mesh sieve	do	20.4
Passing 80-mesh sieve, retained on 100-mesh sieve	do	3.7
Passing 100-mesh sieve, retained on 200-mesh sieve	do	3.7
Passing 200-mesh sieve	do	3.3
Total	do	100.0

Table 16.—*Analysis of water-gas tar preparation used on section No. 1.*

Specific gravity 25°/25° C.		1.091
Viscosity, Engler, 100 c. c. at 50° C., specific		18.4
Free carbon	per cent	2.22

		By volume.	By weight.
Distillation:			
Water	per cent	[1] 0.1	0.1
First light oils to 110° C.	do	[1] .6	.4
Second light oils (110°–170° C.)	do	[1] 1.1	.8
Heavy oils (170°–270° C.)	do	[1] 23.1	20.0
Heavy oils (270°–315° C.)	do	[2] 10.5	9.5
Pitch residue	do	[3] 64.6	68.8
Total	do	100.0	99.6

TABLE 17.—*Analyses of asphaltic petroleums used on sections Nos. 2 and 4, Washington, D. C., 1914.*

	Section No. 2.	Section No. 4.
Specific gravity 25°/25° C.	0.957	0.936
Flash point ° C.	38	30
Burning point ° C.	70	68
Viscosity, Engler, 50 c. c. at 25° C., specific	104.5	87.5
Loss, 5 hours at 163° C., 20 grams per cent.	26.66	24.01
Float test on residue at 32° C. (time)	5′ 14″	6′ 22″
Float test on residue at 50° C. (time)	1′ 39″	1′ 41″
Percentage of total bitumen insoluble in 86° B. naphtha	8.04	13.94
Fixed carbon per cent.	4.93	7.10
Soluble in CS_2 (total bitumen) do	99.91	99.89
Organic matter, insoluble do	.07	.10
Inorganic matter, insoluble do	.02	.01
Total do	100.00	100.00

In the computation of cost data for the renewal surface treatment, shown in Table 18, the following unit prices were used:

Laborer, per 7½-hour day	$1.75
Cart, per 7½-hour day	3.50
Sand, per cubic yard, on work	1.64
Bituminous material (per gallon):	
Section 1	.100
Section 2	.099
Section 3	.085
Section 4	.0775

TABLE 18.—*Materials and cost data for renewal surface treatments, Department of Agriculture Grounds, Washington, D. C., May 14–20, 1914.*

Section No.	Bituminous material.	Area (square yards).	Quantity of materials per square yard.		Cost per square yard (cents).							
			Bituminous material (gallons).	Sand (cubic yards).	Bituminous material.	Sand.	Cleaning surface.	Repairing surface.	Hauling and applying bituminous material.	Hauling and applying sand.	Miscellaneous.	Total.
1	Water-gas tar preparation	1,363	0.177	0.0063	1.770	1.035	0.205	0.000	0.479	0.538	0.034	4.061
2	Asphaltic petroleum	1,095	.137	.0063	1.36	1.033	.234	.192	.330	.287	.085	3.521
3	Residual petroleum	706	.184	.0063	1.565	1.034	.165	.198	.644	.545	.066	4.217
4	Asphaltic petroleum	1,321	.145	.0065	.133	1.066	.106	.123	.459	.441	.053	3.381

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[1] Clear.

[2] Clear, showed 0.0 per cent insoluble in dimethyl sulphate.

[3] Soft, sticky, semisolid; a 315°–350° C. fraction showed 27.5 per cent, and a 350°–375° C. fraction showed 32.5 per cent insoluble in dimethyl sulphate.

SECTION NO. 1 (REFINED WATER-GAS TAR PREPARATION).

The first 100 feet of this section from the south end presented a markedly different appearance than the remainder, owing to the use on this portion of the section of bituminous materials of apparently different character for the 1914 treatment. The bituminous material used on this 100 feet was that remaining from the original treatment, and yielded a fine-grained, smooth appearance of a yellowish-gray color. The remainder of the section was treated with material obtained during the summer of 1914, and the treatment, which had at the time of inspection a reddish-brown color, had largely worn off in well-defined areas, showing the smooth mosaic surface of the original treatment. The section was smooth and had a true crown and uniform cross section.

SECTION NO. 2 (ASPHALTIC PETROLEUM).

This section, although it had a good crown, had developed several small pot-holes, which were rapidly becoming deeper, and along the south edge toward the east end of the section the drainage from the embankment adjoining the road had evidently been instrumental in causing deterioration of the surface mat. A surface treatment will be required the coming season.

SECTION NO. 3 (RESIDUAL PETROLEUM).

The surface treatment applied on this section during the summer of 1914, like the previous treatment, has shown a tendency to become muddy in wet weather and to shove gradually toward the side of the road. At the time of inspection the mat in the traveled way was largely worn off. Several small pot-holes were scattered over the road, and adjoining the Thirteenth Street intersection and toward Twelfth Street there were several large worn depressions which would require extensive patching. In general the road had a smooth regular crown and a smooth mealy surface.

SECTION NO. 4 (ASPHALTIC PETROLEUM).

This section had a smooth, hard surface free from waves and an especially good crown. Along the middle of the road there was evidence of slight and uniform wear over large areas, and the underlying macadam was beginning to show.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD. 1912.

BITUMINOUS CONCRETE, CEMENT CONCRETE, OIL-CEMENT CONCRETE, VITRIFIED BRICK, BITUMINOUS SURFACE TREATMENTS ON CONCRETE.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads and U. S. Department of Agriculture Bulletin No. 105. The following report covers the condition of the experiments when inspected on March 14, 1915.

EXPERIMENT NO. 1 (BITUMINOUS CONCRETE—TOPEKA SPECIFICATION).

This experiment presents a hard firm surface, with some slight indication of waviness. The latter condition is most pronounced in the trap-rock section adjacent to the curb. The wear in this pavement is most evident where the surface is slightly below the top of the concrete curb, and in one place this has been broken and a slight depression has developed. The trap-rock section has a slightly darker color than that in which limestone was used, and the line between the two is easily discernible. Two lateral cracks were noted in the limestone section about 20 and 40 feet, respectively, south of its juncture with the trap-rock section. These cracks extend from the west curb about half way across the road. A small cup-hole was noted in the middle of the road about 60 feet north of Bradley Lane.

EXPERIMENT NO. 2 (BITUMINOUS CONCRETE—DISTRICT OF COLUMBIA SPECIFICATION).

This experiment presents a smooth uniform surface on which the seal coat still remains practically intact. Two lateral cracks, both beginning at the east curb, were noted near the middle of the section in which trap rock was used. One of these extends about one-quarter of the distance across the road and the other about one-half the distance.

During the early summer of 1914 expansion in the concrete again caused a buckling of the surface at the joint between experiments Nos. 2 and 3. The stress developed was sufficient to force out the bricks which had been used in providing for this condition previously. The bricks were therefore removed, a clean trench was cut out entirely across the pavement for a width of about 1 foot and filled with Portland cement concrete.

EXPERIMENT NO. 3 (CEMENT CONCRETE AND OIL-CEMENT CONCRETE—SURFACES TREATED WITH BITUMINOUS MATERIALS).

The several sections of this experiment have been permitted to wear without repairs, and the condition of the various sections at the time of this inspection was noted as follows:

(A) *Refined coal tar.*—The surface treatment has worn off in fairly large areas throughout the entire section.

(B) *Water-gas tar preparation No. 2.*—The surface has worn off in small areas throughout the entire section, in most cases not exceeding 1 square foot. This section is in an appreciably better condition than No. 1 through its retention of more of the original treatment.

(C) *Fluxed native asphalt No. 2.*—The bitumen in this section is still quite pliable, but the surface treatment has largely worn off over the west half of the section, and there are a number of small worn areas in the east half.

(D) *Fluxed native asphalt No. 2 over water-gas tar preparation No. 1.*—The surface treatment is almost intact on the north half of this section, and the bitumen is still pliable. Over the south half, which includes the intersection with Thornapple Street, the surface treatment is in general worn off.

(E) *Fluxed native asphalt over native asphalt emulsion.*—The surface treatment is about two-thirds worn off this section, and the mat appears to be rather brittle.

(F) *Oil asphalt No. 1 over water-gas tar preparation No. 1.*—The surface treatment is almost entirely gone from this section.

(G) *Refined coal tar.*—The surface treatment is worn off to a great extent over the entire section.

(H) *Water-gas tar preparation No. 2.*—The surface treatment is still largely intact, although there are quite a number of small areas ranging in size from one-half square foot to 1 square foot where it is worn off. The majority of these are west of the center line of the roadway.

(I) *Fluxed native asphalt No. 2.*—On the east half of the roadway the surface treatment remains in fairly good condition, but the bitumen has become hard, and the surface treatment has disappeared from more than half of the area west of the center line of the roadway.

(J) *Oil asphalt No. 2.*—On the west third of this section, adjacent to the gutter, the surface treatment is about one-fourth gone, while over the remainder it is practically intact, excepting for one worn place about 1 square foot in area. Apparently the bitumen still possesses life.

Experiment No. 4 (Oil-Cement Concrete) and Experiment No. 5 (Cement Concrete).

No particular difference was noted in the relative wear on the two classes of concrete. It is, however, interesting to note the difference in wear on the section constructed with trap rock on the grade adjacent to the vitrified brick experiment. The west half of the road, which carries the heavy traffic coming up the hill, is worn to an appreciably greater extent than the east half. The mortar appears to have abraded from around the particles of rock, thus yielding a much roughened surface. Over the remainder of the concrete experiment, extending south from the brow of the hill, the wear has been quite uniform over the entire surface. The table following shows the distance between cracks when measured on March 10, 1915.

TABLE 19.—*Average and maximum distance between cracks in concrete experiments at Chevy Chase, Md., March 10, 1915.*

Character of pavement.		Length.	Average distance between cracks.	Maximum distance between cracks.
Concrete.	Aggregate.			
Surface coated with bituminous material:		*Feet.*	*Feet.*	*Feet.*
Cement	Gravel	675	37	90
Do	Limestone	575	64	139
Oil-cement	Gravel	370	25	55
Do	Limestone	226	75	77
Surface exposed:				
Cement	Gravel	425	27	63
Do	Limestone	625	78	148
Do	Trap	300	23	50
Oil-cement	Gravel	260	26	47
Do	Limestone	200	50	84
Do	Trap	290	36	60

As noted in the previous progress report, the relative distances between cracks continue greater on sections constructed with a limestone aggregate than on those where trap rock or gravel were used.

EXPERIMENT NO. 6 (VITRIFIED BRICK).

An inspection of this experiment showed no appreciable difference in wear between the several brands of brick. Three longitudinal cracks were noted, as follows:

In section D, a crack about one-third the length of the section and about 6 feet from the west curb. In section F, a crack about half the length of the section, beginning at the south end, and about 6 feet from the east curb. In section G, a crack about 6 feet long and about the same distance from the east curb as that in section F. These cracks are practically straight and so fine that they would hardly be distinguished in a casual observation. Their cause has not thus far been clearly ascertained.

A traffic census on this experimental road is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between March 1, 1914, and March 1, 1915, is given in Table 20. The east side of the road carries outgoing traffic and the west side incoming traffic.

TABLE 20.—*Volume and character of traffic on Connecticut Avenue north and south of Bradley Lane.*

Vehicle.	North of Bradley Lane.				South of Bradley Lane.			
	Maximum.		Average.		Maximum.		Average.	
	East.	West.	East.	West.	East.	West.	East.	West.
Loaded 1-horse wagon	11	25	4	13	20	18	10	9
Unloaded 1-horse wagon	8	24	3	11	17	20	8	9
Loaded 2-horse wagon	15	103	6	35	32	96	12	28
Unloaded 2-horse wagon	40	75	10	19	83	52	25	10
Loaded 4-horse wagon	2	5	0	1	5	5	0	1
Unloaded 4-horse wagon	2	2	0	0	2	1	0	0
1-horse pleasure vehicle	7	18	3	8	21	18	8	8
2-horse pleasure vehicle	3	3	0	1	20	5	2	1
Rubber-tired horse vehicle	1	2	0	0	12	14	1	0
Saddle horse	8	12	2	3	15	11	3	4
Motor cycle	17	42	4	15	39	33	13	11
Excessively heavy vehicle	3	11	0	1	5	5	1	1
Motor runabout	23	173	7	54	169	139	60	44
Motor touring car	137	308	30	129	454	335	151	117
Loaded motor dray	12	47	4	20	31	34	19	14
Unloaded motor dray	14	20	2	8	17	19	5	8

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD., 1911 PROJECT.

BITUMINOUS CONSTRUCTION AND SURFACE TREATMENT.

The original reports of these experiments are given in Circulars Nos. 98 and 99, Office of Public Roads, and a supplementary report in U. S. Department of Agriculture Bulletin No. 105. The following report is based upon an inspection made January 28, 1915, after an extended period of cold wet weather.

SECTION NO. 1 (REFINED COAL TAR—PENETRATION METHOD).

In the summer of 1914 the surface presented a well-bound but rough appearance and gave evidence of considerable wear on the stone of the upper course. Therefore, on August 5 a cold surface treatment was applied, using a crude coal tar of the analysis given in the following table:

TABLE 21.—*Analysis of crude coal tar[1] used in cold surface treatment of section No. 1.*

Specific gravity 25°/25° C		1. 146	
Specific viscosity, 50 c. c., 50 ° C		5. 0	
Free carbon	per cent	8. 62	
Distillation:		By volume.	By weight.
Water	per cent	[2] 3. 5	3. 0
First light oils to 110° C	do	[3] 3. 3	2. 5
Second light oils (110°–170° C.)	do	[3] . 5	. 5
Heavy oils (170°–270° C.)	do	[3] 23. 0	20. 0
Heavy oils (270°–315° C.)	do	[4] 12. 5	11. 3
Pitch residue	do	[5] 57. 2	62. 4
Total	do	100. 0	99. 7

[1] Thin fluid. [2] Ammoniacal. [3] Clear. [4] One-third solid. [5] Hard, fairly dull, brittle.

The surface was swept by means of a rotary broom drawn by the automobile distributor, which applied the bituminous material. The application was immediately covered with $\frac{3}{8}$-inch washed gravel, and the road opened to traffic. The bituminous material is charged at the rate of 6.6 cents per gallon, and sweeping and applying at 2.5 cents per gallon. The cost data for the treatment are given in Table 24. When inspected the surface was smooth and hard, with but few irregularities.

SECTION NO. 2 (REFINED COAL TAR—MODIFIED GLADWELL METHOD).

This section, although presenting a well-bound surface, is irregular and shows considerable wear, so that a surface treatment will be necessary during the coming season.

SECTION NO. 3 (FLUXED NATIVE ASPHALT—PENETRATION METHOD).

This section continues to present a smooth, well-crowned surface, but during the past year the seal coat has worn so that at the present time the surface has a mosaic appearance in some areas. There are a few other areas, especially in the north half of the section, where the seal coat is still intact, and no general treatment will be required during the coming season.

SECTION NO. 4 (GILSONITE OIL ASPHALT—PENETRATION METHOD).

This section, although well bound together, has an irregular surface, especially toward the gutter, so that it is rather rough under automobile traffic. In the depressions the stones are generally exposed, and probably considerable patching will be necessary in the spring.

SECTION NO. 5 (OIL ASPHALT—PENETRATION METHOD).

The appearance of this section has not changed appreciably since the last inspection, described in U. S. Department of Agriculture Bulletin No. 105. The surface is uneven, and in a few depressions the stone is somewhat loose. No raveling has occurred, however, and only minor repairs are now required.

SECTION NO. 6 (OIL ASPHALT—PENETRATION METHOD).

In general, this section has the same appearance as section No. 5. At the north end and on the west side of the trolley tracks the grade is 2 to 3 inches lower than that of the adjoining asphaltic concrete experiment, and it will be necessary in the spring to bring the surface to a corresponding grade.

SECTION NO. 7 (A AND B; OIL ASPHALT—PENETRATION METHOD).

The appearance of this section is not uniform. A has quite a mosaic effect, the northern portion of B has several small breaks which will need patching in the near future, and the southern portion has developed a few slight irregularities.

SECTION NO. 8 (REFINED WATER-GAS TAR PREPARATION—SURFACE TREATMENT).

The surface presents a very uneven appearance, owing apparently to the motion of the surface mat under traffic. A few small chuck holes have formed where raveling seems imminent, although in general the surface is very well bound. The section will probably require some repair and a surface treatment during the coming spring.

SECTION NO. 9 (ASPHALTIC PETROLEUM—SURFACE TREATMENT).

Toward the close of the season of 1914 this section began to give evidence of considerable wear. As in previous seasons, deterioration became more marked in the third of the road nearest the gutter and was most evident over the south half of the section, where an exceedingly heavy rain had interrupted the progress of the previous surface treatment. Two badly raveled places, each about half a square yard in area, and a few smaller depressions were patched by the penetration method with new 1½-inch limestone and a heavy oil-asphalt, rolled with a 10-ton roller, and finished by the application of a seal coat of the same bituminous material. Several humps were removed by cutting them flush with the surface by means of a mattock.

Immediately after these repairs had been made, on October 17 and 19, a surface treatment was applied over the entire section, using the same trade product as in the two previous treatments, and a fine torpedo sand. The surface was first thoroughly swept with fiber hand brooms, and the oil applied by allowing it to run from the bungs of the barrels and distributing it with push brooms. The oil was immediately covered with sand and the road opened to traffic. The bituminous material cost 8 cents per gallon, and the sand cost $2.12 per cubic yard on the work.

Table 22 gives an analysis of the bituminous material, and the cost of surface treatment is given in Table 24.

TABLE 22.—*Analysis of asphaltic petroleum* [1] *used in surface treatment of section No. 9.*

Specific gravity, 25°/25° C.		0.964
Flash point	°C.	40
Burning point	°C.	85
Specific viscosity, Engler, 25° C., 50 c. c.		113.3
Loss, 5 hours at 163° C., 20 grams	per cent.	26.46
Float test of residue [2] at 32° C. (time)		3′ 46″
Float test of residue at 50° C. (time)		1′ 21″
Percentage of total bitumen insoluble in 86° B. naphtha		7.43
Fixed carbon	per cent.	5.04
Soluble in CS_2 (total bitumen)	do.	99.92
Organic matter insoluble	do.	.06
Inorganic matter insoluble	do.	.02
Total	do.	100.00

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[1] Fairly viscous, sticky fluid.

[2] Very viscous, sticky fluid; glossy.

At the time of inspection the section generally presented a firm smooth surface. A few small cup-holes had formed where repairs were made before the last surface treatment, and were undoubtedly due to a poor distribution of oil asphalt in placing the patches.

SECTION NO. 10 (RESIDUAL PETROLEUM—SURFACE TREATMENT).

The development of irregular humps and ruts upon this section, noted in U. S. Department of Agriculture Bulletin No. 105, continued during the past year, until the surface was in such condition that it was deemed advisable to remove the surface mat as far as possible and re-treat the entire section. Accordingly the surface mat was broken up by means of a 3-ton scarifier, and as much of it removed as could be easily separated from the macadam stone. The old surface was then loosened by scarifying and picking, shaped with rakes, and brought to grade by the addition of a thin course of ¾-inch limestone. After rolling, limestone screenings were scattered over the surface just sufficient in quantity to fill the surface voids. The surface was then thoroughly bonded by sprinkling with water and rolling.

The following table gives the materials and cost data per square yard for the reconstruction of the water-bound macadam surface.

TABLE 23.—*Materials and cost data for reconstruction of section No. 10, Chevy Chase, Md.*

Materials used per square yard:		
1½-inch limestone	cubic yard	0.001
¾-inch limestone	do	.016
Limestone screenings	do	.007
Cost per square yard:		
1½-inch limestone	cents	.173
¾-inch limestone	do	4.060
Limestone screenings	do	1.823
Sweeping old surface	do	.145
Removing old surface mat	do	2.970
Scarifying, and raking scarified surface	do	2.674
Spreading stone	do	1.041
Sprinkling	do	.764
Rolling	do	2.979
Total	do	16.629

On November 3 and 4, after several days' traffic over the water-bound surface, the section was given a cold surface treatment with an asphaltic petroleum of the analysis given in Table 22. This was covered with washed ⅜-inch gravel. The bituminous material was applied by allowing it to run from the bungs of the barrels directly upon the road, which had previously been swept with hand brooms to remove loose material. The oil was broomed over the surface until no uncoated spots remained, and it was found that considerable brooming was necessary, owing to the fairly large amount of dust still remaining. The oil was almost immediately covered with gravel, and finally the entire section was rolled lightly with an 8-ton tandem roller. After several days' traffic a subsequent light application of sand was found necessary to absorb the bituminous material that came to the surface. The material and cost data for the surface treatment is given in Table 24.

At the time of inspection the section had passed through a long spell of unfavorable weather, and its appearance demonstrated that the treatment was applied too late in the season. Numerous small but deep cup-holes had formed, extending into the water-bound macadam, and in general the entire surface had become very muddy. Considerable patching will be necessary at an early date.

SECTION NO. 11 (NATIVE ASPHALT EMULSION—MACADAM RESURFACING).

The section has had no treatment since it was resurfaced, and during the past year it has worn very uniformly, so that at the time of inspection the large stones were generally exposed over the entire surface. There are a few long waves and in a few places the large stones have apparently broken under traffic, but otherwise the surface is in excellent condition.

MAINTENANCE DURING THE YEAR 1914.

In addition to the general re-treatment above described, the patrol system of maintenance was continued during the year. Table 25 presents the total cost of this maintenance and the re-treatments, together with the total cost of each experiment to December 31, 1914.

A traffic census is taken every 13 days for a 24-hour period. A tabulation of the maximum and average of each class of traffic for the period between March 1, 1914, and March 1, 1915, is given in Table 20. The east side of the road carries outgoing traffic and the west side incoming traffic.

TABLE 24.—*Materials and cost data for surface treatment in 1914 of sections 1, 9, and 10 at Chevy Chase, Md., 1911 project.*

Section No.	Bituminous material.	Area of section (square yards).	Quantity of material per square yard.			Cost per square yard (cents).							
			Bituminous material (gallons).	Gravel (cubic yard).	Sand (cubic yard).	Bituminous material.	Gravel (cubic yard).	Sand (cubic yard).	Cleaning surface.	Applying bituminous material.	Applying sand or gravel.	Rolling.	Total.
1	Coal tar, crude	1,581	0.316	0.007	......	2.088	1.538	......	......	[1]0.791	0.625	......	5.042
9	Asphaltic petroleum	761	.209	......	0.0085	1.672	......	1.811	0.356	.436	.434	......	4.709
10	do	1,013	.476	.011	.0020	3.807	2.328	.419	.339	.548	.571	0.099	8.111

[1] Includes cost of sweeping.

TABLE 25.—*Surface maintenance of 1911 experiments at Chevy Chase, Md., to December 31, 1914.*

Experiment No.	Date completed.	Area (square yards).	Maintenance cost of experiment.				Cost per square yard (cents).		
			1912	1913	1914	Total.	Construction.	Maintenance.	Total.
	1911.								
1	Oct. 31	1,581	$0.00	$0.00	$91.33	$91.33	46.18	5.777	51.96
2	...do....	705	.00	.00	.00	.00	77.62	.000	77.62
3	Nov. 18	1,555	.00	.00	.00	.00	64.69	.000	64.69
4	Nov. 8	1,555	.00	4.05	1.90	5.95	57.16	.383	57.54
5	Dec. 2	1,447	260.26	2.31	.67	263.24	58.27	18.192	76.46
6	Nov. 23	1,555	.00	3.47	.00	3.47	68.22	.223	68.44
7A	Dec. 5	131	1.43	.00	.00	1.43	59.96	1.092	61.05
7B	...do....	848	67.88	.00	1.33	69.21	54.80	8.162	62.96
	1912.								
8	Aug. 24	1,477	....	80.64	.00	80.64	39.59	5.460	45.05
9	June 4	761	....	39.65	44.78	84.43	42.01	11.095	53.11
10	Nov. 22	1,013	....	19.05	284.04	303.09	44.31	29.920	74.23
11	Dec. 16	377	....	.00	.00	.00	81.51	.000	81.51

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT JAMAICA, N. Y., 1911.

OIL-CEMENT CONCRETE, OIL-ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

The original report of these experiments was published in Circular No. 98, and reports of annual inspection and repairs may be found in Circular No. 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers the condition of the sections when inspected January 18, 1915.

EXPERIMENT NO. 1 (OIL-CEMENT CONCRETE).

In May, 1914, the Borough of Queens highway department patched the bare spots which were reported in the inspection of December, 1913, with an application of hot, refined coal tar and sand, and the addition of ¾-inch stone in the deeper holes. The bare spots had developed somewhat larger in the section treated with water-gas tar products than in that treated with refined coal tar. At the time of the inspection the entire section was in very good condition with the exception of about 20 small bare spots where the carpet coat had worn off. The entire coat seemed to be worn very thin.

EXPERIMENT NO. 2 (CUT-BACK OIL ASPHALT—MIXING METHOD).

In May, 1914, the condition of this experiment was a little worse than in December, 1913, and in consequence the entire section was scarified to a depth of 3 inches and about one-third of the soft bituminous top mixture was thrown away. The remaining mixture was then shaped and lightly rolled to a thickness of about 2 inches, after which it was covered with a thin layer of ¾-inch stone, thoroughly rolled, and opened to traffic. The following day a thin layer of trap-rock screenings was rolled in.

At the time of the inspection the experiment was again in very bad condition, and it appeared to be breaking up throughout its entire length. Numerous potholes, extending through the full thickness of the road, were forming, and the bituminous material appeared to have lost its life. The easterly 50 feet, however, continued in somewhat better condition than the remainder of the experiment.

EXPERIMENT No. 3 (FLUXED NATIVE ASPHALT—MIXING METHOD).

Except where openings have been made for house connections, at about stations 5+40, 5+80, and 6+80, this section remains in very good condition. The patches placed at the openings are now somewhat below the original grade. Along the north side for the last 30 feet and for a width of from 3 to 4 feet there are a few waves about 3 feet long and 1 inch or less in depth. It is also possible in wet weather to notice slight waves, perhaps not over one-sixteenth inch in depth, extending entirely across the roadway. These were evidently caused by the manner of pouring the seal coat at the time of construction.

EXPERIMENT No. 4 (REFINED COAL TAR—MIXING METHOD).

This section is in excellent condition except for the following imperfections: The edges on both sides are a little wavy, the waviness being more pronounced between stations 8+00 and 8+45 for a width of 5 feet on the north edge and between stations 8+45 and 9+00 on the south edge for a width of about 10 feet. At station 9+54 a pothole is forming on the north edge. The seal coat is gone from stations 10+68 to 10+98 for a width of about 5 feet on the south edge. At station 10+90, on the north side, a house connection was made and as the work of restoration was not properly done, the pavement at this point is not in first-class condition.

EXPERIMENT No. 5 (CUT-BACK OIL ASPHALT—MIXING METHOD).

A rut developed in this section during the winter of 1913–14, and this, together with the holes reported in the last inspection report, was repaired in May, 1914. The deeper holes were patched with 1½-inch stone and hot refined coal tar, applied by the penetration method at the rate of 1½ gallons to the square yard. The rut was patched with ¾-inch stone, sand, and hot refined coal tar.

At the time of inspection the surface of the following portions of the experiment was found to be good: An irregular strip through the center from 6 to 8 feet in width, the whole intersection opposite Hardenbrook Street for a width of about 35 feet, the south side from stations 13+00 to 13+23, and the north side from stations 12+50 to 13+94. Over the remainder of the experiment the seal coat is disappearing, and potholes are forming. The whole section is wavy on the edges, particularly the north edge, and there are indications that the bituminous material is losing its life. A pothole is forming just south of the center and on the west side of a patch at station 13+23.

EXPERIMENT NO. 6 (OIL ASPHALT—PENETRATION METHOD).

This section continues in good condition, except for the fact that the seal coat seems to be wearing, while it is nearly gone on a strip about 2 feet wide 8 or 9 feet in from the south side from station 13+94 to station 14+38. The bituminous material of the seal coat over this area seems to lack life, and indications are that the strip will extend to the eastward. There is a narrow strip south of the center where the seal coat has been picked up by the wheels of some heavily loaded vehicle.

EXPERIMENT NO. 7 (REFINED COAL-TAR—PENETRATION METHOD).

The general condition of this section is good. The surface is very satisfactory in the center, but along the sides the seal coat appears thin and is gradually disappearing. There is a bad depression on the north side at the junction of experiments Nos. 6 and 7, and three potholes were observed to be developing along the south side at stations 16+03, 16+15, and 16+94, respectively. The patch previously made over the conduit across the roadway is in excellent condition, but where one was made at station 16+90 near the south edge of the roadway the surface is below grade. Other than as above noted, the condition of this experiment remains about the same as when inspected, in December, 1913.

EXPERIMENT NO. 8 (FLUXED NATIVE ASPHALT—PENETRATION METHOD).

This section is in about the same condition as reported in U. S. Department of Agriculture Bulletin No. 105, with the exception that a slight waviness has developed over the entire roadway. This is more noticeable at the sides, where the excess of bituminous material used in the original construction has pushed out.

EXPERIMENT NO. 9 (OIL ASPHALT—PENETRATION METHOD).

The surface of this experiment is in good condition, with the exception of a few spots where the seal coat has been picked up or worn off, and these have partially healed over. Some would not be noticeable except on a rainy day. From station 19+20 to station 19+34 the seal coat has been worn off in the center of the road. From station 19+34 to the east end of the experiment there is a narrow strip where the seal coat was partially stripped off by the wheel of some heavily loaded vehicle.

There are some waves on the edges and a small hump on the south side at about station 18+54. The work done to fill in between this section and the wood-block pavement east of the experiment is in very poor condition; the seal coat is gone, and quite a number of potholes have been formed, especially on the south side.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEW YORK, N. Y., AND RIDGEWOOD, N. J., 1910.

OIL-CEMENT CONCRETE.

The original report of these experiments was published in Circular No. 94, and the reports of annual inspections appeared in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made in October, 1914.

EXPERIMENTS AT NEW YORK, N. Y.

This roadway was torn out in its entirety the week of September 27, 1914. The general condition of the surface of the road had gradually deteriorated from the condition shown by the inspection reported in December, 1913, and it was decided by the road maintenance department of the Borough of Richmond that the entire roadway should be torn up and a new one laid. It has therefore been replaced by bituminous concrete on a cement-concrete foundation.

EXPERIMENTS AT RIDGEWOOD, N. J.

Experiment No. 1.—The oil-cement concrete floor of the bridge over Saddle River was covered with a bituminous surfacing, as reported in the inspection made in December, 1913. The bituminous-macadam surfacing is in first-class condition, and the oil-cement concrete is not exposed.

Experiment No. 2.—The oil-cement concrete floor of the bridge over the Hohokus River is apparently in similar condition to that reported in December, 1913, excepting for the fact that it is a little more worn. The surface is even and smooth and has a rather flat cross section. The wear on this bridge floor still continues in the center of the roadway, since the sides for a width of from 3 to 4 feet from each edge are protected by dirt and leaves. In the center the large stones of the aggregate show on the surface, and at the ends of the bridge the edges of the concrete are rounded off to meet the surface of the adjoining macadam road.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT BOISE, IDAHO, 1910.

OIL-GRAVEL MACADAM.

The original report of this experiment was published in Circular No. 94, and reports of annual inspections were given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made on January 2, 1915:

The section which was constructed directly under the supervision of the Office of Public Roads carries voluminous and heavy suburban traffic, both vehicle and motor, and has received no maintenance or repairs since its original construction. A new 40-foot steel truss bridge was constructed across the slough last October, which resulted in unusually heavy additional traffic. For 20 feet on either side of the new bridge the macadam has been destroyed. The remainder of the experiment now presents an unsatisfactory appearance and is very wavy and much worn. There is a series of potholes of various sizes and depths, but there is, however, no apparent disintegration. The former shoulders have been used as a roadway until they have worn through the subgrade and are largely used by lighter traffic to avoid jolting. The crown is well maintained, and the penetration has been effective in general, with an excess of oil in places. The unevenness of wear, as previously noted, has been due primarily to a weak and poorly prepared foundation. Wherever the bond is broken the contributory cause appears to be large water-worn gravel too near the surface, and lack of uniformity in the distribution of the bituminous material, which latter permits early raveling.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT AMES, IOWA, 1910.

OIL-ASPHALT GRAVEL.

The original report of this experiment was published in Circular No. 94, and reports of annual inspections were given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105.

When visited on December 19, 1914, there was about 1 inch of snow on this road. Scraping this snow from spots revealed about one-half inch of oily dust, covering a well-bonded surface. On warming bits of bituminous material in the hands it still developed a perceptible stickiness.

It was learned that an attempt was made in August to remove certain irregularities on the surface and to raise the center of the crown by means of a light two-wheeled single-blade grader. This cut away the high smooth places on the surface, leaving the gravelly mixture exposed. However, the traffic compacted this surface and it bonded again in very good shape. There was and is now some roughness perceptible to automobile travel caused by the uneven distribution of the material which was brought to the center for the purpose of raising the crown.

Traffic on this road is considerable, although it consists mainly of automobiles, carriages, and light wagons, since most of the heavy trucking enters the college grounds by another road.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT KNOXVILLE, TENN., 1910.

TAR AND OIL PREPARATIONS.

The original report of these experiments was published in Circular No. 94, and reports of annual inspections are given in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The sections were again inspected November 18, 1914, and the following report was made:

The weather had been dry for some time, and the temperature was slightly above freezing. No repairs have been made or maintenance work done during the past year.

Section 1 (Refined Coal Tar—Penetration Method).

This section is worn out, and the only places showing that tar was applied are those areas which were repaired a short time after the road was constructed. These patches stand out as islands about 2 inches above the surface of the road. Along each edge of the original pavement is a border of the tar mat from 12 to 18 inches in width and of varying thickness, caused by bleeding of the tar. Between these borders the surface has worn down to the foundation course of stone except at the islands referred to. This course of stone is wearing unevenly, and save for a few places where the tar penetrated it is water-bound macadam. It serves no further useful purpose as an experiment and should be rebuilt.

Section No. 2 (Refined Tar Preparation—Penetration Method).

Between the south end of this section and a street intersection 340 feet north, the surface is a succession of depressions and holes. About 300 feet from the south end of the section the tar-treated wearing course is continuous across the pavement for a short length, affording the first opportunity of studying the cross section of the pavement as affected by wear only. From the street intersection northward for some distance the surface is in fairly good condition; and although it is pitted with depressions of various sizes, there are few holes. In the last 100 feet there are quite a few holes, especially on the west side. This section should be reconstructed.

Section No. 3 (Oil-Asphalt—Penetration Method).

Except for a few depressions on the west side, the surface presents an excellent appearance. It has worn down to the wearing stone in places, resembling a bitumen-bound mosaic, but in no place has it lost its character as a bituminous surface, nor is there any evidence of raveling. Throughout the traveled portion the cross section is uniformly well preserved. Such bitumen as was dug out with a knife blade was tough and pliable. The section will not require repairs to keep it in serviceable condition, but should the other sections be reconstructed the depressions in this section ought to be brought to grade.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT YOUNGSTOWN, OHIO, 1909.

SLAG, SLAG AND LIME, SLAG AND WASTE SULPHITE LIQUOR PREPARATION, AND SLAG AND TAR.

The original report of these experiments was published in Circular No. 92, and reports of annual inspections were given in Circulars Nos. 94, 98, and 99, Office of Public Roads, and U. S. Department of Agriculture Bulletin No. 105. The following report covers an inspection made October 26, 1914, after a period of about 10 days' rain:

SECTION NO. 1 (BLAST-FURNACE SLAG).

A length of approximately 65 feet of this section, beginning at the south curb of Mahoning Avenue, has been surfaced with a bituminous paving material and serves as an intersection apron to that avenue. Beyond the end of this pavement the section has not been disturbed, and it is in generally good condition. The ruts have become well defined, but they are shallow and wide, except for three depressions about 30 inches long in the west rut. In these depressions the binder has disappeared from the surface interstices of the stone of the wearing course, but the stones do not appear to have been loosened. The surface is otherwise smooth, uniformly worn, and free from large protruding stones.

SECTION NO. 2 (BLAST-FURNACE SLAG AND LIME).

Wide shallow ruts extend the entire length of the section, and a few large stones about 3 inches in diameter protrude about one-half inch above the general surface. Aside from these, the section has a clean-cut appearance and does not appear badly worn.

SECTION NO. 3 (BLAST-FURNACE SLAG AND WASTE SULPHITE LIQUOR PREPARATION).

The ruts referred to in the two preceding sections continue unbroken to the top of the slight grade near the middle of section No. 3, and there is no noteworthy difference in appearance between this and the preceding section. About the same number of large pieces of slag protrude from a unit of area, and there is no visible difference in wear. From the middle of the section down the grade to the beginning of section No. 4, neither the ruts nor the protruding stone are as pronounced as in the north half of the section.

SECTION NO. 4 (BLAST-FURNACE SLAG AND REFINED COKE-OVEN TAR).

The middle third of this section has settled very unevenly. Sand and slag chips have lodged in the depressions, from several of which the tar has entirely disappeared; in others, the pavement itself is disintegrating. The tar is hard and "dead," and the stone and tar can be separated under heel pressure. The ridges between the depressions are cracking.

While not as uneven as the middle third, the two end thirds are beginning to fail. The surface is so full of irregularities that riding over it is uncomfortable. In no place does the surface seem to have failed, but the tar is dry and lusterless and can be readily separated from the stone.

SECTION NO. 5 (BLAST-FURNACE SLAG).

Section No. 5 is still about 1½ inches below section No. 4 at their junction. The northern two-thirds of this section is on a grade in a cut which shows evidence of seepage water. The surface of the road is rutted wider and deeper over this part of the section than over any other part of the experiments. However, there is no indication of failure of the pavement through raveling in the ruts. The south one-third of the section has a very satisfactory appearance; the ruts are not more than one-fourth inch deep, and the surface has a smooth, evenly worn, and uniform appearance.

SECTION NO. 6 (BLAST-FURNACE SLAG).

This section is wearing down into wide deep ruts. While in general the east rut is more pronounced than the west, there are several elongated depressions in the latter which have been swept clean of their binder and look as though they would ravel when dry. There are also three small spots in the section that seem to be the result of settlement rather than wear. The entire surface is mottled with large stone about 3 inches in diameter, protruding above the general surface.

SECTION NO. 7 (BLAST-FURNACE SLAG AND OPEN-HEARTH SLAG).

Some time during the summer, section No. 7 was swept clean of its screenings and dust, apparently in preparation for a surface treatment. In spite of this, there is no evidence of raveling. The whole section shows wide shallow ruts, with the large pieces of slag protruding. On the fill, from 100 to 200 feet from the south end of the section, the west rut is between 2 and 3 inches deep, and the depression over the culvert at the north end of the fill is a menace to traffic.

About 50 feet of the south end of the section was given a surface treatment of asphaltic oil during the summer when Price Road was treated. The treatment has worn uniformly.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT NEWTON, MASS., 1908.

ASPHALTIC PREPARATIONS, TAR PREPARATIONS, RESIDUAL OIL, AND MOLASSES-OIL-LIME.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections were given in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. No repairs have been made during the past year, and the following report covers an inspection made on October 5, 1914.

Experiments Nos. 1, 2, 3, 4, 5, 6, and 7 (Asphaltic Preparation—Mixing Method).

The first four of these sections, which have been reported as badly worn and in need of resurfacing, have continued to deteriorate so that almost none of the original surfacing shows. All of these sections are badly rutted and full of holes, with the exception of one piece of road, about 30 feet in length, at or near the beginning of experiment No. 3. This is in practically perfect condition for the entire width of the roadway.

Experiment No. 5 in its entirety is now in about the same condition as the first four experiments and is in need of resurfacing.

Experiment No. 6 continues to be in very good condition.

Experiment No. 7 contains about 20 places varying from depressions to holes, with about 14 holes which vary from 6 inches in diameter to an area of 4 square feet. It is evidently deteriorating rapidly through the "cupping" action. The three holes reported in Circular No. 99 as needing patching now show only traces of the binder, but there is a good mechanical bond in the foundation stone.

Experiment No. 8 (Residual Petroleum—Mixing Method).

The eight small holes which were reported in U. S. Department of Agriculture Bulletin No. 105 have developed so that they vary from 6 inches in diameter to an area of 2 square feet. On this section there are indications of rutting and raveling near each quarter-point. The section should be patched and surface-treated if further deterioration is to be prevented, otherwise it seems probable that an inspection next year will show that it will need resurfacing. At the westerly side of Langdon Street there is evidence of a trench having been dug across the entire roadway in order to supply a fire hydrant, and the old material has been thrown back without any attempt at surface patching.

Experiments Nos. 9 and 10 (Refined Water-gas Tar—Mixing Method).

These experiments appeared to be in practically as perfect condition as reported in U. S. Department of Agriculture Bulletin No. 105.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT GARDEN CITY, DODGE CITY, BUCKLIN, AND FORD, KANS., 1908.

SAND-CLAY.

The original report of these experiments was published in Circular No. 90, and reports of annual inspections are given in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The following are reports of inspections made in 1914:

Experiment at Garden City.

This road was inspected November 10, 1914, and wheat hauling with 4-horse teams was in progress at that time. There had been practically no rain since June, but the road had not deteriorated seriously.

There are no unrepaired holes. On the day of inspection 12 small holes and depressions were filled with fresh clay. There are five depressions varying from 2 feet square to 5 feet square which should be filled with clay before they are cut through.

The entire section has gradually flattened and should be reshaped. There are long wide ruts from one-half to three-fourths inch deep and the entire surface is finely pitted. It is not so rough, however, as to make riding uncomfortable.

The road is being maintained by dragging and by filling worn places in the manner indicated.

Experiments at Dodge City.

This road was inspected November 10, 1914. There had been no rain in this vicinity for some time and the soil was very dry. Wheat was being hauled to market, and the road was in such poor condition that the traffic from a large territory used a roadway 1 mile east of this.

About two-fifths of the sand-clay surface was broken through, and the sand from below had come to the surface. The failure had taken place over irregular areas. In some places it was confined to the rut or to the middle half of the road. There were occasional stretches 30 or 40 feet long that were in excellent condition. Consequently, the surface was so irregular and so deeply cut that traffic was confined to the ditches entirely.

The failure was no doubt largely due to the fact that the road had not been properly dragged after the heavy spring rains, and the weak places developed at that time were worn through by the heavy traffic during the long drought of the ensuing summer and autumn.

The road is now beyond repair, and reconstruction is necessary.

EXPERIMENT AT BUCKLIN.

This road was inspected November 11, 1914, when wheat hauling had begun.

The cross section of the road had gradually flattened, and two wide ruts (12 inches wide by 1 inch deep) had formed throughout its entire length. There were numerous places where the surface had begun to fail in the ruts, but only a few where the sand-clay surface had entirely cut through. The largest of the latter were in the immediate approach to the bridge. There were about 25 depressions and 5 holes through the surface.

Outside the ruts a slight ridge had formed, the outer edges of which were overgrown with grass. The ditches were covered with a heavy growth of grass, but were well defined and open.

The depressions and holes should be filled with clay, and the road should be reshaped with a grader to prevent the formation of secondary ditches inside the existing ones.

EXPERIMENT AT FORD.

This road was inspected November 11, 1914. It was generally in good condition except within 100 feet of the bridge, where there were three holes cut through the sand-clay surface. In the remainder of the road there were several depressions which should be filled with fresh clay before dragging the road. There were two ruts extending the entire length of the road, which were about 12 inches wide and 1 inch deep. The ditches were well defined, and the roadway would be in excellent condition if it were dragged and repairs made at the places noted.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT BOWLING GREEN, KY., 1907.

KENTUCKY ROCK ASPHALT.

The original report of this experiment was published in Circular No. 89, and reports of annual inspections are given in Circulars Nos. 90, 92, 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletin No. 105. The inspection on which the following report is based was made on November 5, 1914.

The experiment has had no maintenance whatever, and owing to the accumulation of dirt on the surface it was impossible to make a thorough inspection. Such information as could be gained by cleaning the surface in places and digging into depressions seemed to indicate that the condition was not greatly changed since the last inspection. There are numerous holes throughout the west end, but the relative number decreases as the east end is approached. In many of these holes the rock asphalt has practically disappeared, and the remaining stones are loose. In areas where the rock asphalt has not failed the surface remains quite smooth.

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